Office Use Only	
Project Code	
Project Type	

FINAL REPORT 2024

Final reports must be submitted using the online application form at www.sagit.com.au with this Word document attached ***within two months*** after the completion of the Project Term.

PROJECT CODE	AGS 04922
PROJECT TITLE	
Sulphur dynamics and budgets in two contrasting soil profiles	

PROJECT DURATION *These dates **must** be the same as those stated in the Funding Agreement.*						
Project start date	**1/07/2022**					
Project end date	**30/06/2024**					
SAGIT Funding	2022/23		2023/24		(year)	$

PRINCIPAL INVESTIGATOR *(responsible for the overall project and reporting)*			
Title:	**First Name:**		**Surname:**
Dr.	Sean		Mason
Organisation:	**Agronomy Solutions Pty. Ltd.**		
Mailing address:			
Telephone:		**Email:**	
Mobile:			

ADMINISTRATION CONTACT DETAILS *(responsible for all administrative matters relating to project)*			
Title:	**First Name:**		**Surname:**
Ms.	Stephanie		Zanker
Organisation:	**Agronomy Solutions Pty. Ltd.**		
Mailing address:			
Telephone:		**Email:**	
Mobile:			

PROJECT REPORT: *Please provide a clear description for each of the following:*

Executive Summary (200 words maximum)

- After a wet season (2022) Sulphur moved to 60-80 cm in a sandy profile and 20-40 cm in loam profile regardless of form from either SOA or Gypsum.
- Further S movement of 2022 applications occurred through the 2023 season with S moving out of the 1m profile in the sand and down to 40-80cm on the loam where constraints exist at the 60-80cm layer.
- Assumptions that available S forms from previous seasons additions through either SOA or Gypsum should not be made as on selected season x soil profiles (low CEC), mobility of S could be out of reach from rooting systems.
- Neither high yielding Wheat (2022) nor Barley (2023) responded to application of S in either form even though starting profile S levels at the sand site were below critical levels at shallow depths. This highlights the importance of treating S like N by converting profile S results to supply in kg/ha and comparing this with predicted crop S requirements for diagnosis of S deficiency.
- Sulphur applied as elemental S reduced leaching effects, but this was primarily due to low conversion to sulphate and plant/soil available forms.

Project objectives

This small demonstration project will aim to provide valuable information on immediate and longer-term Sulphur management options applicable to a wide range of growing regions.

The project aims will be achieved by:
1) Comparing different forms of Sulphur fertilizers for mobility and availability within soil profiles with detailed profile sampling.
2) Impact of two different crop types in Sulphur accessibility due to varying rooting depths.

Overall Performance

This project we believe has achieved the aims set out in the research proposals with a couple of tweaks worth mentioning.
Unfortunately, and ideally, we were keen to select a site x season where S deficiency was expressed, and we could highlight the efficiencies of each treatment at correcting the S deficiency.
We had originally planned to grow lentils in the second season, but this was changed to Barley on the back of the grower's decision to change rotations. We believe optimal sowing conditions in both seasons generating high yields and reasonable S demand may have compensated for this change in crop for the second season.
As outlined in future work the trial design could be replicated on a sandier soil type with a crop that has high S demand (e.g. canola) which might add some value to these outcomes.
We have essentially highlighted that S mobility should be a management consideration on selected soil types, and this is the first time we believe a team has successfully tracked recent additions of S from three different products.

Agronomy Solutions would like to highlight and acknowledge the quality work of Trengove Consulting who formed a large part of this project and continue to deliver exceptional trials with quality results and we enjoy the collaboration on all fronts.

KEY PERFORMANCE INDICATORS (KPI)		
KPI	**Achieved**	**If not achieved, please state reason.**
Site selection (one paddock, two sites)	Yes ☒ No ☐	
Implementation and completion of two replicated trials – all soil and plant sampling (year 1)	Yes ☒ No ☐	
Progress report submitted to SAGIT	Yes ☒ No ☐	
Implementation and completion of two replicated trials – all soil and plant sampling (year 2)	Yes ☒ No ☐	
Progress report submitted to SAGIT	Yes ☒ No ☐	
Final report submitted to SAGIT	Yes ☒ No ☐	

TECHNICAL INFORMATION (Not to exceed **three** pages)

Site Characteristics

Two replicated trials were set up in accordance with other trial work through Trengove Consulting. The target aim for the sites was one trial on a loam soil profile and the other on a sand soil profile to enable a comparison of S movement with product in two contrasting soil types. Pre sowing soil analysis confirmed adequate location of both trials in adjacent paddocks near Bute (not in the same paddock) (Table 1). Further analysis can be found in the supplement (table S2). The sand site had no soil constraints to sampling depth of 1m with below critical S values found between 10-40cm. CEC as a measure of potential nutrient retention was low to moderate at the surface but quickly increased with depth. Sand profiles can be significantly lower in CEC than this site. At the loam site constraints started to occur between 60-80cm with increased salinity and boron levels. Sulphur levels were good in association with greater CEC levels and Organic Carbon (table S2).

Table 1: Selected site soil characteristics of S product trials located near Bute.

Depth (cm)	Sand Site					Loam Site				
	MCP S (mg/kg)	CEC	Clay %	Boron (mg/kg)	Sodium %	MCP S (mg/kg)	CEC	Clay %	Boron (mg/kg)	Sodium %
0-10	5.8	9.3	<1	0.5	0.8	7.9	25	12	1.8	0.4
10-20	2.9	8.7	8	0.5	0.6	5.2	29	19	1.7	0.5
20-40	2.5	18	6	0.6	0.3	7.2	31	26	2.3	0.9
40-60	4.6	21	9	0.8	0.3	9.1	31	23	2.5	1.8
60-80	8	23	10	1.1	0.4	11	29	24	5.7	6.7
80-100	7	24	14	1.1	0.5	28	30	22	16	15.8

2022 and 2023 Climatic Conditions

Full rainfall patterns for the 2022 and 2023 season from the nearest BOM site at Bute suggested an average (decile 5) season in 2023 following an exceptional 2022 season Decile 8-9 (table S1, table 2). We were hopeful that the difference in rainfall recorded between trial years would help outline the potential mobility of S at the two contrasting sites.

Table 2: Summary of growing season rainfall (GSR) and yearly rainfall for the 2022 and 2023 season recorded at Bute.

Season	GSR (mm) Apr-Nov	Yearly Rainfall (mm)
2022	330	450
2023	230	360

2022 and 2023 Grain Yield Results

In 2022 both sites were sown to wheat with increasing rates of Sulphur applied as either Elemental S, Sulphate of Ammonia and Gypsum. An additional Gypsum treatment was applied which represented typical grower rates if Gypsum was decided to be required as an amelioration option (5t/ha). Trial design enabled the testing of Sulphur applied in 2022 with that applied additionally in 2023. We therefore had 6 replicates in 2022 and 3 replicates in 2023 with half of the 2022 treatments replicated in 2023.

Throughout 2022 there was no significant increase in NDVI taken at GS30 and GS40, Plant S concentrations at GS40 at both sites which could be attributed to S. There was a small boost in NDVI metrics with the highest SOA rates which was attributed to increased N applications. Given the large amount of N applied at the top SOA rate it was decided for crop safety that N rates at the 100 kg S/ha as SOA would be balanced. These N rates were appropriate to maximize yields in an adjacent N banking trial on the Sand site.

Grain yields for 2022 were high and ranged from 6.19 to 6.91 t/ha on the sand site and 6.14 to 6.59 t/ha at the loam site. Even though the large crop would have placed a reasonable demand for soil S on the sand site (low S) there was no significant treatment effect on grain yields (table 3). Under adequate S conditions for the loam site there was a significant treatment x rate interaction ($p < 0.001$) but this was attributed to the negative effect of the two highest rates of SOA.

In 2023 the sites were sown to Barley in coordination with the main crop grown in the paddock and in line with 2022 there was no treatment effects on NDVI taken at GS30 and GS40, Plant S concentrations at GS40 at both sites which could be attributed to S. Grain yields were still high and ranged from 4.62 to 5.23 t/ha on the sand site and 4.86 to 5.23 t/ha at the loam site. There was no treatment x S rate effect at either site (table 3). In either season there was no significant increase in grain S concentrations with S treatments and therefore no differences in overall S uptake/removal off the paddock for any treatment combination. This highlights the need to use profile S measurements in a similar fashion to N budgets by converting S measurements to profile S and compare these values to crop S requirements.

Table 3: Mean grain yields (Wheat – 2022, Barley – 2023) for each Sulphur product x rate applied either solely in 2022 or in both 2022 and 2023 for the Sand and Loam sites.

			2022				2023	
Treatment no	Product	2022 S applied (kg/ha)	Sand Site Grain Yield (t/ha)	Loam Site Grain Yield (t/ha)	2023 S applied	Total S applied (kg/ha)	Sand Site Grain Yield (t/ha)	Loam Site Grain Yield (t/ha)
1	Nil	0	6.46	6.54	0	0	4.858	4.917
2	Gypsum	50	6.49	6.52	0	50	5.266	5.067
3	Gypsum	100	6.56	6.49	0	100	5.069	5.069
4	Gypsum	200	6.43	6.42	0	200	4.964	5.069
5	Gypsum	750	6.55	6.36	0	750	5.021	5.011
6	SOA	10	6.63	6.53	0	10	4.934	4.997
7	SOA	50	6.39	6.52	0	50	4.749	5.165
8	SOA	100	6.19	6.14	0	100	4.816	5.069
9	SOA	200	6.62	6.33	0	200	4.734	5.108
10	Elemental S	10	6.47	6.56	0	10	5.071	4.935
11	Elemental S	50	6.91	6.55	0	50	5.091	4.956
12	Elemental S	100	6.58	6.52	0	100	4.788	4.993
13	Elemental S	200	6.51	6.59	0	200	4.949	5.011
14	Nil	0			0	0	5.197	5.028
15	Gypsum	50			50	100	4.902	5.015
16	Gypsum	100			100	200	5.135	5.095
17	Gypsum	200			200	400	4.939	5.081
18	Gypsum	750			750	1500	4.954	4.952
19	SOA	10			10	20	4.697	5.075
20	SOA	50			50	100	4.737	5.188
21	SOA	100			100	200	4.622	5.233
22	SOA	200			200	400	4.912	4.857
23	Elemental S	10			10	20	4.821	5.089
24	Elemental S	50			50	100	4.863	5.009
25	Elemental S	100			100	200	5.233	4.97
26	Elemental S	200			200	400	5.087	5.011
		P value	0.284	<0.001		P value	0.814	0.368
		LSD	NS	0.24		LSD	NS	NS

Sulphur movement within two contrasting profiles

Detailed soil sampling post each trial season and prior to the next season for selected treatments at both sites revealed that S forms from both SOA and Gypsum are highly mobile and can move freely through the profile in two seasons with moderate to high rainfall (figure 1). The slightly contrasting rainfall seasons post S application meant that mobility was reflective of soil water moving through the profile. In brief, the majority of SOA applied in the 2022 season moved to the 60-80cm layer at the sand site and 20-40cm layer at the loam site. By the end of the 2023 season the 2022 application of Sulphur had started to move out of the 1m profile at the sand site and moved down to the 40-60cm layer at the loam site. The addition of fresh Sulphur in 2023 revealed that during the lower rainfall season, Sulphur had moved predominantly to the 40-60cm layer in the sand and equally distributed between 10 and 40cm at the loam site. Full profile results for each S product across both sites and seasons can be found in the supplementary report (figure S1 and S2). In brief, Elemental S provided little (not significant) increase in profile S levels suggesting the makeup of these soils were unable to breakdown the elemental S form into sulphate as measured by extraction techniques. Elemental S might be an option in high leaching environments (low CEC) at keeping S in the soil profile but supply might not be enough to keep up with crop demand for S in a deficient scenario. The sulphate form from SOA appears to be slightly less mobile than the sulphate form from Gypsum. This highlights that the source of sulphate from Gypsum can't be assumed to remain within the soil profiles of some soil types.

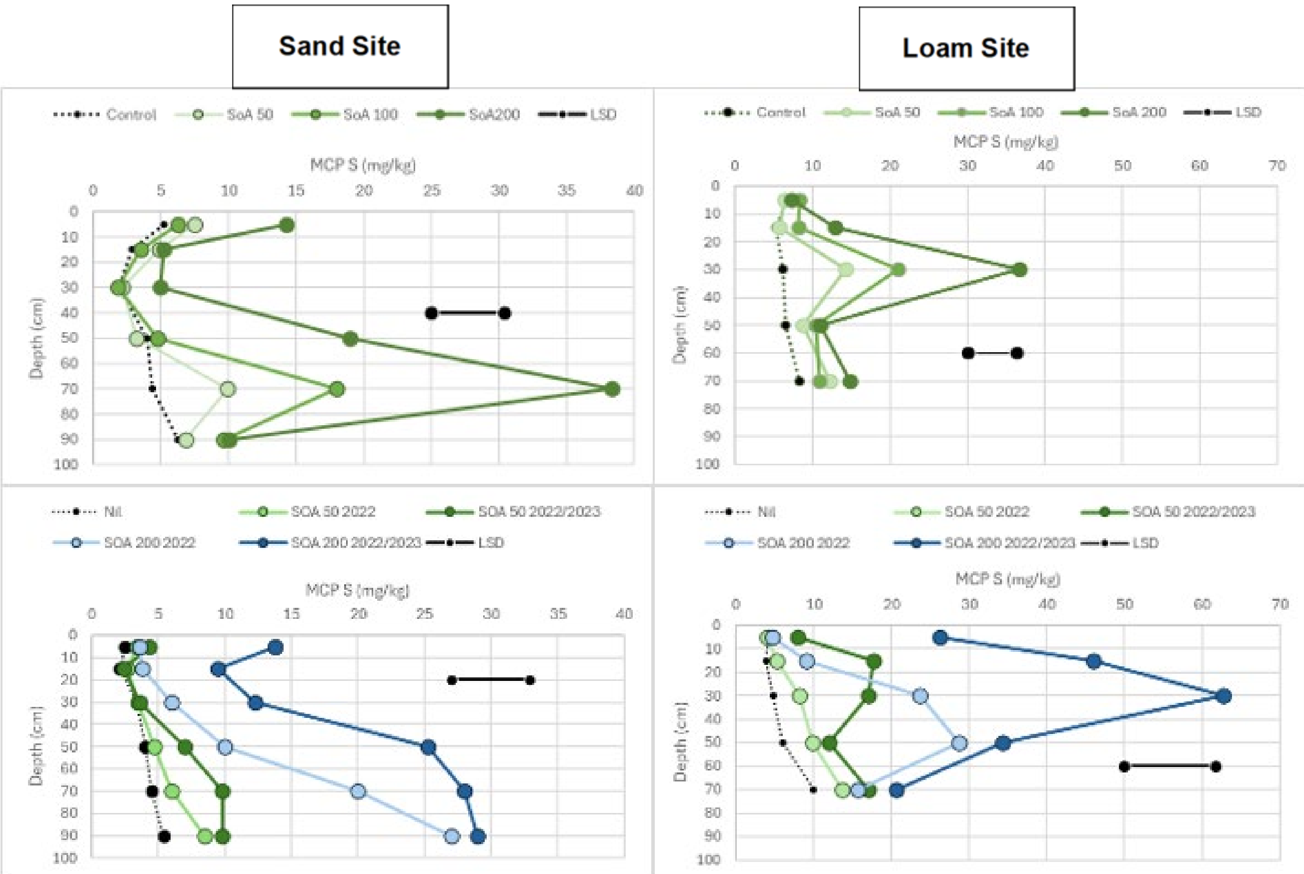

Figure 1: Mean profile S results as measured by MCP S extraction for the sand site (left) and loam site (right) with applied S as SOA in 2022/sampled 2023 (top) and combination of 2022/2023 S applications/sampled in 2024 (bottom). All datasets generated a highly significant interaction ($p<0.01$) with LSD bars presented in each sampling x site activity. The first number represents an S rate and second is year applied.

Sulphur budgets

Mass balance calculations of S after the 2023 season and sampling in 2024 using the control as the baseline highlighted the efficiencies or retention of each product x rate either applied in 2022 or a combination of 2022/2023. These results assume the MCP extraction measures the available S pool with potential contributions to the total S soil pool as a possibility. The results highlight the potential loss pathways for each soil profile. Elemental S had low recoveries presumed not through leaching but by conversion to available form. For the sand site, 2022 applications on average resulted in 30-35% recovery in the soil profile which assumes the potential of 60-65% loss beyond the 1m sampled. Recoveries from 2023 applications were higher 55-65% potentially due to the lower rainfall season. There were limited differences between S applied either through SOA or Gypsum on recoveries. Higher recoveries were observed for the loam site within the sampling depth but there is the potential that some available S forms have moved to hostile layers and inaccessible for crop uptake.

Table 4: Mass balance calculations for a combination of treatments applied in 2022 and 2022/2023 using the control as the baseline. Available S measurements (MCP) were converted to kg/ha and increases above the control were calculated as a % of the total S applied. Grain S uptake results were incorporated in these calculations but varied little between treatments.

					Sand Site		Loam Site	
Trt_Number	S Product	S rate (kg/ha)	Year of application	Total S rate (kg/ha)	MCP S (kg/ha	% S in MCP pool	MCP S (kg/ha	% S in MCP pool
1	Nil	0	2022	0	56		70	
2	Elemental S	200	2022	200	69	7	126	28
3	Elemental S	200	2022/2023	400	73	4	107	9
4	SOA	50	2022	50	73	35	84	28
5	SOA	50	2022/2023	100	95	39	180	110
6	SOA	200	2022	200	189	66	225	77
7	SOA	200	2022 & 2023	400	302	62	451	95
8	Gypsum	50	2022	50	62	12	95	50
9	Gypsum	50	2022/2023	100	112	56	137	67
10	Gypsum	200	2022	200	118	31	209	69
11	Gypsum	200	2022/2023	400	285	57	500	107
12	Gypsum	758	2022	758	308	33	668	79
13	Gypsum	758	2022 & 2023	1516	984	61	1196	74

CONCLUSIONS REACHED &/OR DISCOVERIES MADE (Not to exceed <u>one</u> page)

- Mobility of Sulphur from recent applications can be quite high and is controlled by soil profile characteristics.
- After a wet season (2022) Sulphur moved to 60-80 cm in a sandy profile and 20-40 cm in loam profile regardless of form from either SOA or Gypsum.
- Further S movement of 2022 applications occurred through the 2023 season with S moving out of the 1m profile in the sand and down to 40-80cm on the loam where constraints exist at the 60-80cm layer.
- Full recoveries in available S form from S applied in the 2022 season were between 30-35% on the sand and 55-65% on the loam when sampled prior to the 2024 season.
- Recoveries in available S form were higher from 2023 applications in line with time of sampling in 2024 and in the range of 56-100% depending on treatment and site.
- Assumptions that available S forms from previous seasons additions through either SOA or Gypsum should not be made as on selected season x soil profiles (low CEC), mobility of S could be out of reach from rooting systems.
- If Sulphur deficiency is suspected on sandier soil types small and frequent additions should be made to improve Sulphur crop use efficiency.
- Neither high yielding Wheat (2022) nor Barley (2023) responded to application of S in either form even though starting profile S levels at the sand site were below critical levels at shallow depths. This highlights the importance of treating S like N by converting profile S results to supply in kg/ha and comparing this with predicted crop S requirements for diagnosis of S deficiency.
- Sulphur applied as elemental S reduced leaching effects, but this was primarily due to low conversion to sulphate and plant/soil available forms.

INTELLECTUAL PROPERTY
None

APPLICATION / COMMUNICATION OF RESULTS
The trial sites have been showcased as part of NSS 2023 field days and an Independent Consultants field tour where 2022 results were discussed. Sean Mason presented these findings to an Elders agronomy meeting held at Waite campus on the 5th of February 2024. Sulphur chemistry and mobility is now included in soil and plant test interpretation presentations provided by Agronomy Solutions. The 2024 soil sampling program, now completed, allows for further communication opportunities as these results complete the project aims nicely. We will endeavor to promote the results through 2024 farming systems compendiums.

POSSIBLE FUTURE WORK
We believe this project has completed the Sulphur story in terms of improved management. The only possibility would be to replicate this project on lower CEC soil types and grow crops with greater S demand (e.g. Canola).